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551.542 : 553.21 : 551.577

# Pressure fields over Indian Seas and their relationships with Indian summer monsoon rainfall

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**सार**—आई०एन०सी०एल०आई० के 15 वर्षों (1976-90) के आंकड़ों का उपयोग करके, हिन्दमहासागर पर चतुष्कोणीय ग्रिडों के लिए, धरातलीय वायुदाब की मासिक असंगतियों का परिकलन किया गया है। ग्रिडों की वायुदाब असंगतियों और भारतवर्ष में होने वाली ग्रीष्मकालीन मानसूनी वर्षा के मध्य संभावित सम्बन्धों पर भी चर्चा की गई है। मई की वायुदाब असंगतियों और मानसूनी वर्षा के बीच अच्छे सह-सम्बन्ध पाए गए हैं।

ABSTRACT. Monthly anomalies of surface pressure for quadrangular grids over Indian Seas have been computed utilising 15 years' INCLI data (1976-90). The relationships between the grid pressure anomalies and summer monsoon rainfall over India have been discussed. Good correlations have been found between the anomalies of May and the monsoon rainfall.

**Key Words** — INCLI (report of monthly means of surface pressure for the Indian Ocean), Pressure anomalies, Correlation coefficient, Long-range forecasting.

## 1. Introduction

It is generally recognised that the distributions of atmospheric and oceanographic parameters over Indian Seas play a key role in the performance of Indian summer monsoon. Recent studies (Dube *et al.* 1990, Gopalakrishna *et al.* 1988 a, b and Joseph 1981) indicated that much of the year-to-year variability of the summer monsoon rainfall over India may be due to the variations of oceanic parameters. Ranjit Singh (1980, 1983) studied the Sea Surface Temperature (SST) and pressure patterns over north Indian Ocean utilising the data of *Marine Climatological Summaries*. He found higher SST and lower surface pressure over most of the oceanic areas during good monsoon years. The aim of present study is to look into the probable relationships between the pressure anomalies over Indian Seas and the monsoon rainfall. Correlation Coefficients (CCs) between the anomalies over Arabian Sea and Bay of Bengal and the seasonal and monthly rainfall departures for India as a whole have been computed.

## 2. Data and methodology

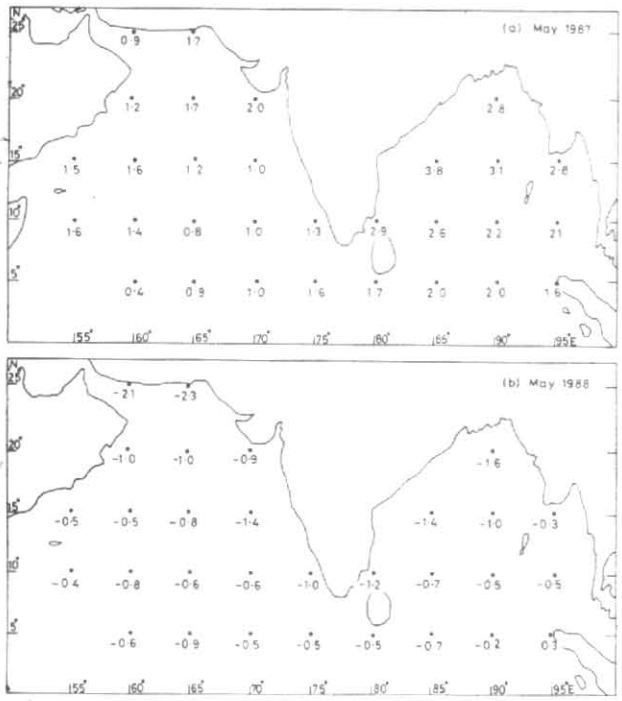
Monthly normals of surface pressure for 5° × 5° grids over Arabian Sea and Bay of Bengal were worked out for pre-monsoon and monsoon months (March-September) utilising the reports of monthly means of surface pressure for Indian Ocean derived from the ships' observations for the period 1976-90. As an international commitment the reports of monthly means of surface pressure are transmitted on Global Telecommunication System (GTS) every month. Such reports for Indian Ocean are known as INCLI (IN—Indian Ocean, CLI—climate). In the computations of the monthly normal for a particular grid point all reports (1976-90) of that month for that grid point were used. The mean monthly pressure value for a grid point in the INCLI data is obtained from all ships' observations recorded in the neighbourhood of that grid point during that particular month. Monthly anomalies for each grid point have been computed for individual years.

Indian monsoon rainfall data given by Thapliyal (1990) and periodical publications of *Mausam* have been used. The following sets of CCs have been computed :

(a) CCs between mean monthly anomalies (May-August) over Arabian Sea and monthly rainfall departures (June-September) for India as a whole with a lag of one month.

(b) CCs between monthly anomalies over Arabian Sea and the corresponding monthly rainfall departures for India as a whole (June-September) without lag.

(c) CCs between the mean seasonal pressure anomalies over Arabian Sea and all India summer monsoon (June-September) rainfall departures.




**Figs. 1 (a & b).** Distribution of pressure anomalies during (a) May 1987, and (b) May 1988

(d) CCs between mean monthly anomalies (May-September) over Arabian Sea and seasonal (June-September) rainfall departures for India as a whole.

(e) CCs for individual grid points over Arabian Sea. Similar CCs (a-e) have been computed for Bay of Bengal separately.

## 3. Results and discussion

### 3.1. *CCs between mean monthly anomalies and monthly rainfall departures (with a lag of one month)*

Mean pressure anomalies for every month (May-August) have been worked out for Arabian Sea and Bay of Bengal. All grid-anomalies over Arabian Sea have been considered in the computation of mean anomalies over Arabian Sea. Similarly, mean anomalies over Bay of Bengal have been obtained by taking average of all grid-anomalies over Bay of Bengal. The CCs between mean monthly anomalies and all India rainfall departures of succeeding months have been computed. It is found that good correlations exist between the anomalies of May and the rainfall departures of June. The CCs of other months are insignificant (except the CC between mean anomaly of August over Arabian Sea and rainfall departure of September for India as a whole which is —0.79) and their discussion is omitted. The CCs are given in Table 1. The CC for Arabian Sea mean anomaly of May and all India rainfall departure of June is —0.67 and the corresponding CC value for Bay of Bengal is —0.70; both CCs being significant at 1% level.

The above CCs indicate that negative pressure anomalies over Arabian Sea and Bay of Bengal during the month of May are conducive for better monsoon rainfall over India during the month of June. However, CC values of June and July show that no significant correlations exist between the pressure anomalies of June-July over Indian Seas and the rainfall of succeeding months (July-August). Negative pressure anomalies over Arabian Sea during August appear to be favourable for good monsoon activity over India during the month of September.

The results of this section may find some application in the long-range forecasting (of time-scale of one month) of Indian summer monsoon rainfall.

### 3.2. *CCs between monthly anomalies and the rainfall departures of the same months (without lag)*

The CCs between the anomalies and the rainfall of same months (given in Table 2) show that negative pressure anomalies over Indian Seas during July correspond to good rainfall activity over India during July. No significant correlations have been found during June, August and September. CC values for July for Arabian Sea and Bay of Bengal are —0.74 (significant at 1% level) and —0.54 (significant at 0.5% level) respectively. These correlations may have some applications in the medium range forecasting of summer monsoon rainfall over India during the month of July.

### 3.3. *CCs between the mean seasonal anomalies and all India summer monsoon rainfall departures*

The CCs between the mean pressure anomalies of March-April-May (MAM) and June-July-August (JJA) over Arabian Sea and Bay of Bengal and all India rainfall departures of summer monsoon are shown in Table 3. Good correlation has been found

TABLE 1

**CCs between mean monthly pressure anomalies and all India rainfall departures of succeeding months**

| | May-Jun | Jun-Jul | Jul-Aug | Aug-Sep |
|---|---|---|---|---|
| Arabian Sea | −0.67* | −0.06 | −0.40 | −0.79* |
| Bay of Bengal | −0.70* | +0.24 | +0.09 | +0.29 |

TABLE 2

**CCs between mean monthly pressure anomalies and all India rainfall departures of same months**

| | Jun-Jun | Jul-Jul | Aug-Aug | Sep-Sep |
|---|---|---|---|---|
| Arabian Sea | −0.28 | −0.74* | −0.45 | +0.43 |
| Bay of Bengal | −0.05 | −0.54** | +0.46 | −0.11 |

TABLE 3

**CCs between mean seasonal pressure anomalies and all India rainfall departures of SW monsoon (June-September)**

| | MAM-JJAS | JJA-JJAS |
|---|---|---|
| Arabian Sea | −0.17 | −0.70* |
| Bay of Bengal | −0.14 | +0.06 |

between JJA—pressure anomaly of Arabian Sea and all India summer moonsoon rainfall, which is −0.70 (significant at 1% level). It is interesting to note that the correlation between mean seasonal anomaly of MAM and all India summer monsoon rainfall is not significant.

Thus the mean seasonal pressure anomalies of pre-monsoon over Indian Seas do not provide any predictive indications of ensuing summer monsoon rainfall over India. This led the authors to investigate the correlations between monthly anomalies and the Indian summer monsoon rainfall which is discussed in the next section.

### 3.4. *CCs between the monthly anomalies and all India summer monsoon rainfall departures*

Tables 4 and 5 show the CCs between monthly anomalies and seasonal (June-September) rainfall over India. Negative correlations exist between pressure anomalies over Indian Seas during the month of May and the seasonal rainfall departures.

TABLE 4

**CCs between mean monthly pressure anomalies of pre-monsoon and all India rainfall departures of SW monsoon (June-September)**

| | Mar-JJAS | Apr-JJAS | May-JJAS |
|---|---|---|---|
| Arabian Sea | +0.11 | −0.28 | −0.51** |
| Bay of Bengal | +0.15 | −0.03 | −0.48 |

TABLE 5

**CCs between mean monthly pressure anomalies of SW monsoon and all India rainfall departures of SW monsoon (June-September)**

| | Jun-JJAS | Jul-JJAS | Aug-JJAS | Sep-JJAS |
|---|---|---|---|---|
| Arabian Sea | −0.05 | −0.75* | −0.51** | −0.61** |
| Bay of Bengal | +0.50 | −0.29 | −0.02 | −0.58** |

*Significant at 1% level. ** Significant at 5% level

These CCs for Arabian Sea and Bay of Bengal are −0.51 and −0.48 respectively, the former being significant at 5% level. Though the CCs are not very high yet the distribution of pressure anomalies over Indian Seas during May can provide useful indications of ensuing summer monsoon rainfall over India. The CCs for the remaining two months of pre-monsoon, *i.e.,* March and April are insignificant.

For monsoon months high negative CC is found between July—anomaly of Arabian Sea and all India summer monsoon rainfall, which is −0.75 (significant at 1% level). Corresponding CCs for Arabian Sea anomalies of August and September are −0.51 and −0.61 respectively (both significant at 5% level). Thus the distribution of pressure anomalies over Arabian Sea can be an useful predictor for the southwest monsoon rainfall over India.

### 3.5. *Gridwise distribution of CCs*

#### 3.5.1. *CCs between pressure anomalies of May and rainfall departures of June*

The CCs between the anomalies of May at fixed grid points and the rainfall departure of June have been computed. The distribution of grid-CCs thus obtained has been shown in Table 6. The significant feature revealed by Table 6 is that the pressure anomaly at each individual grid point in May and the rainfall over India during June are negatively

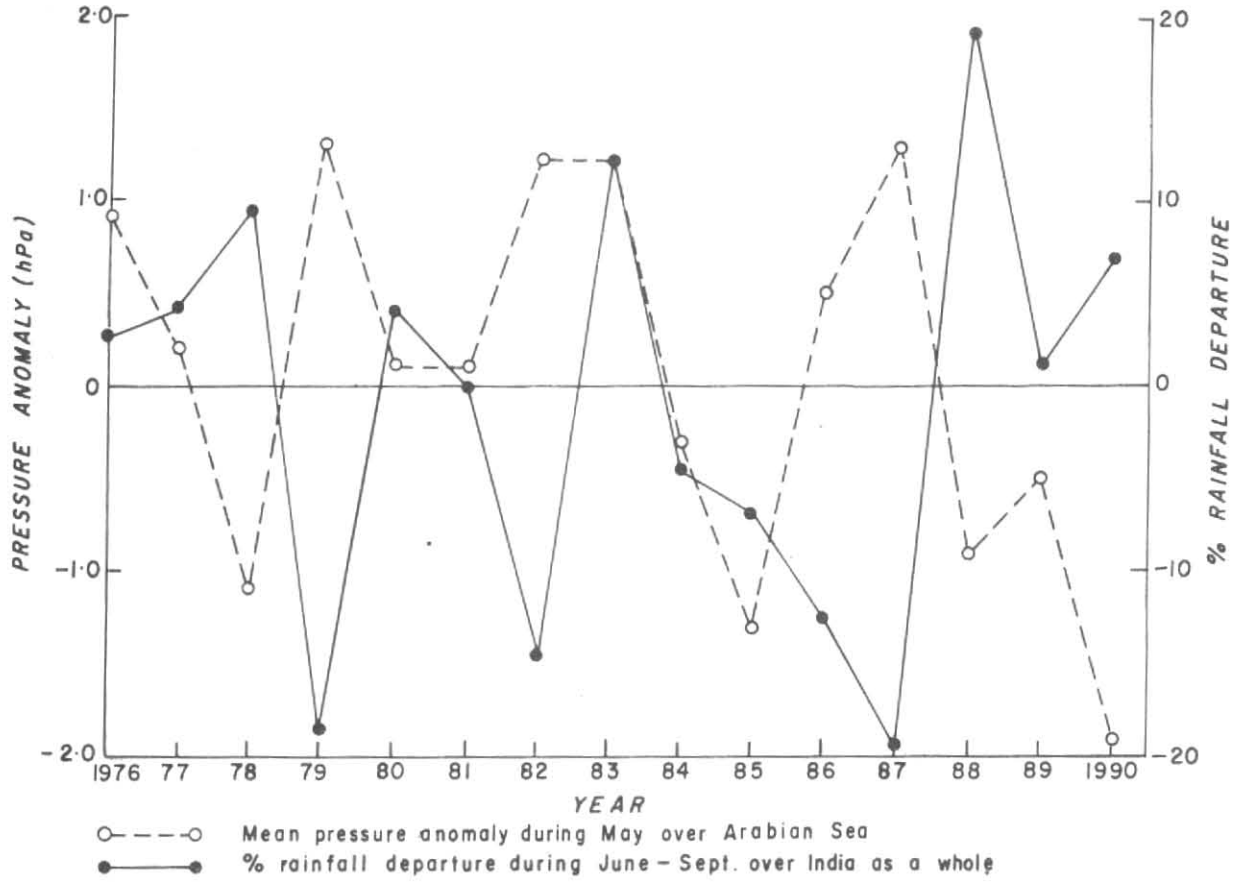



Fig. 2. Interannual variability of May pressure anomalies over Arabian Sea and seasonal (Jun-Sep) rainfall departures over India

correlated. Except for a few grid points the correlations are quite good all over Arabian Sea and Bay of Bengal. The CC-values range from —0.45 to —0.80 (only CCs with $|CC| > 0.60$ have been shown in Table 6). Thus the type of anomalies prevailing over Arabian Sea and Bay of Bengal during May can give predictive indications of ensuing SW monsoon rainfall over India during the month of June.

3.5.2. *Distribution of CCs between pressure anomalies of May and seasonal (June-September) rainfall departures*

The grid-CCs (having absolute values > 0.60) between May-anomalies and seasonal rainfall over India have been shown in Table 7. Highest CC-value is observed over Arabian Sea at the grid point 2.5°N, 60°E, which is —0.78 (significant at 1% level). In general, the CC-values are lower than those shown in Table 6 but all are again negative.

TABLE 6

**Gridwise CCs between May pressure anomalies and all India rainfall departures of June**

| Grid point | CC |
|---|---|
| 25°N, 65°E | —0.73* |
| 20°N, 65°E | —0.64** |
| 20°N, 70°E | —0.64** |
| 20°N, 90°E | —0.68* |
| 15°N, 60°E | —0.74* |
| 15°N, 70°E | —0.60** |
| 15°N, 85°E | —0.61** |
| 15°N, 90°E | —0.73* |
| 10°N, 55°E | —0.74* |
| 10°N, 60°E | —0.69* |
| 10°N, 95°E | —0.60** |
| 5°N, 80°E | —0.80* |
| 5°N, 85°E | —0.74* |
| 5°N, 95°E | —0.63** |

*Significant at 1% level.
**Significant at 5% level.

TABLE 7

**Gridwise CCs between May anomalies and all India rainfall departures of summer monsoon (Jun-Sep)**

| Grid point | CC |
|---|---|
| 25°N, 60°E | —0.78* |
| 25°N, 65°E | —0.60** |
| 15°N, 65°E | —0.60** |
| 5°N, 70°E | —0.66* |

*Significant at 1% level,
**Significant at 5% level.

Therefore, it appears that there exists a definite negative correlation between pressure anomalies of May over Indian Seas and seasonal (June-September) rainfall over India. However, while making any inference about seasonal rainfall it would be advisable to consider the anomalies of those grid points where CCs are high.

### 3.6. *Distributions of pressure anomalies during May of the years 1987 and 1988*

The distributions of anomalies during the month of May of the years 1987 (a dry monsoon year) and 1988 (a wet monsoon year) have been shown in Figs. 1 (a & b) respectively. The years 1987 and 1988 have been particularly chosen due to their contrasting summer monsoons. During 1987, there was a major monsoon failure whereas 1988 was an extremely good monsoon year. The seasonal rainfall departures (June-September) for India as a whole during these years were —19% and +19% respectively. It is seen from Figs. 1 (a & b) that entire area over Arabian Sea and Bay of Bengal was covered with positive pressure anomalies during May 1987 whereas negative anomalies prevailed during May 1988.

### 3.7. *Variability of May-pressure anomalies over Arabian Sea and summer monsoon rainfall departures over India (June-September) for the period 1976-90*

The distributions of mean pressure anomalies of May over Arabian Sea and all India rainfall departures during June-September for the period 1976-90 have been depicted in Fig. 2. The figure clearly brings out the negative correlation between pressure anomalies and rainfall departures.

Negative surface anomalies over Indian Seas during the month of May are, perhaps, conducive for stronger inter-hemispheric pressure gradients just before the commencement of summer monsoon and consequently more rainfall over India. The state of Indian Seas during later period of pre-monsoon season (say during May) appears to play a crucial role in the Indian summer monsoon rainfall.

## 4. Conclusions

The study has brought out the following results :

(*i*) Negative pressure anomalies over Indian Seas during the month of May are associated with good summer monsoon activity over India during the month of June.

(*ii*) Negative pressure anomalies over Indian Seas during July have been found to be associated with good monsoon activity over India during July.

(*iii*) Negative pressure anomalies over Indian Seas during May are correlated to good seasonal (June-September) rainfall over India.

(*iv*) Mean pressure anomaly of August over Arabian Sea is negatively correlated to the September rainfall over India.

(*v*) High negative correlation has been found betwen mean pressure anomalies of June-August (JJA) over Arabian Sea and all Indian summer monsoon rainfall.

A practical aspect of the present study is that the results can be readily applied as the input monthly INCLI data is available immediately after the completion of each month.

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